Validation of IASI EDRs and Prelaunch Characterization of CrIMSS EDRs with IASI EDRs, ECMWF and RAOB Measurements

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Northrop Grumman Aerospace Systems

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MIT Lincoln Laboratory

NASA Sounder Science Team Meeting, November 3-5, 2010, Greenbelt, MD. 1

Outline for Presentation

1. **Quick Summary on Validation Efforts- T(p), q(p), O3(p)**
   - » **What we did for Aqua-AIRS Validations**
   - » **What we have been doing for MetOP- IASI Validations**
   - » **What we have been doing for Both AIRS and IASI Validations**

3. **Transformation to CrIS/ATMS Pre-launch Characterization**
   - » **Generation & Evaluation of CrIS/ATMS Proxy SDRs**
     - • **Data Sets Matched to IASI/AMSU-A/MHS**
       - **MetOP Focus Day Data Sets (ECMWF/NCEP-GFS)**
       - **MetOP Global Data (MGD) RAOB/ECMWF/NCEP-GFS**
     - • **Algorithms To Derive Proxy CrIS/ATMS**
   - » **CrIMSS EDR Product Generation**
     - • CrIMSS_LaRC_V1.5 EDR Algorithm
   - » **Evaluation of CrIMSS (CrIS+ATMS) EDRs With Data Sets Proven Valuable to Global Validations**
     - » **ECMWF, RAOB Measurements/ EDRs from IASI/AMSU/MHS (NUCAPS)**
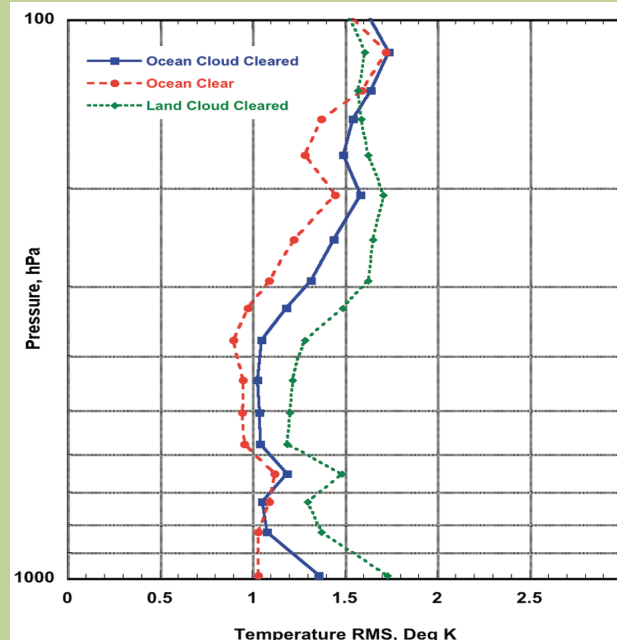   - » **Leverage existing capabilities - STAR/NUCAPS, MIRS, ATOVS**

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Aqua-AIRS T(p), q(p) Validation *(JGR, 2006)*
Data sets Proven Valuable for Global Validation
## RAOBs/ECMWF/NCEP-GFS
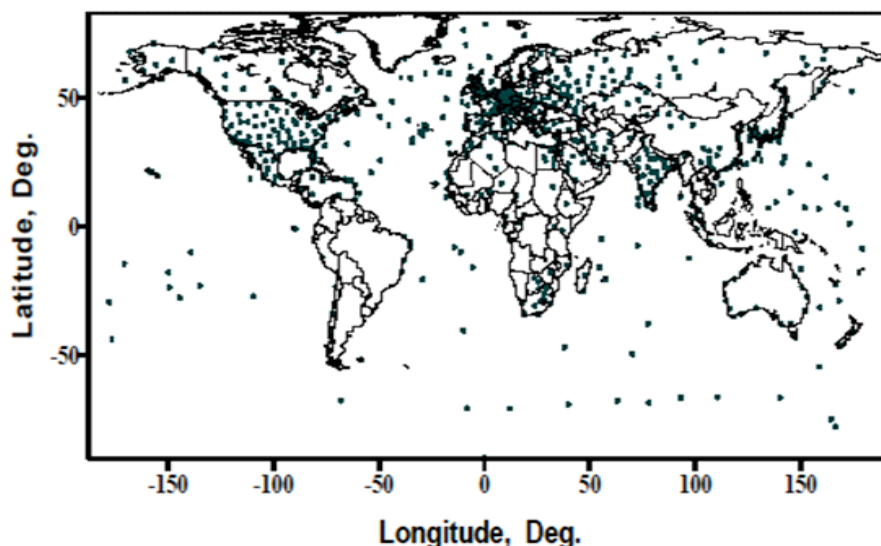
Locations of RAOBs and other Matched Data Sets (ECMWF) Used in Validating AIRS Retrievals   (N ~82,000)

Divakarla et . al., 'Validation of Atmospheric Infrared Sounder temperature and water vapor retrievals with matched radiosonde measurements and forecasts , J. Geophys. Res., 111, D09S15, doi:10.1029/2005JD006116.
http://www.agu.org/pubs/crossref/2006/2005JD006116.shtml

Chahine et al ., 'AIRS: Improving Weather Forecasting and Providing New Data on Greenhouse Gases , Bulletin of the American Meteorological Society , 2006; 87: 911-926.
http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-87-7-911
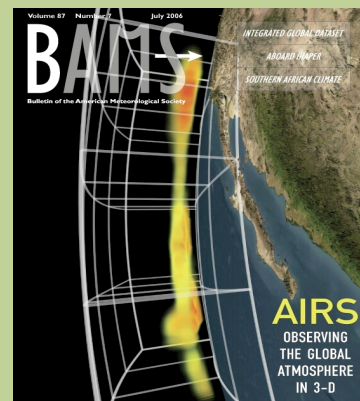
AIRS
Temperature: 1K/1Km
Moisture: 15%
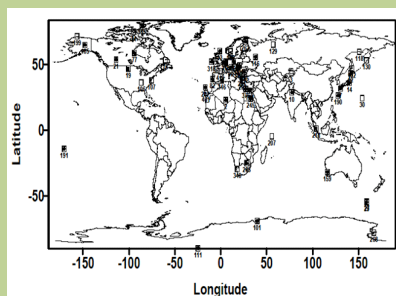**Ozone: 10%**
On Accepted Samples

IASI
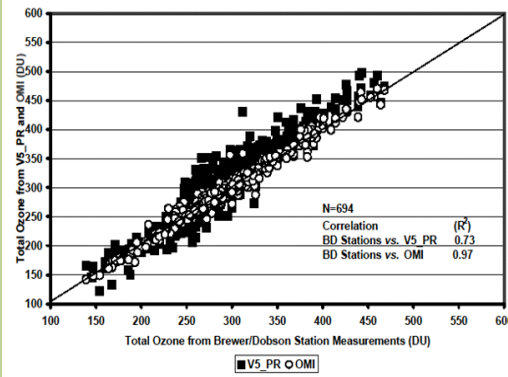**Similar to AIRS**

CrIS/ATMS
1.6K/Km Globally

Aqua-AIRS Ozone Validation, (JGR, 2008)
WOUDC O3(p), TO3 BD Measurements
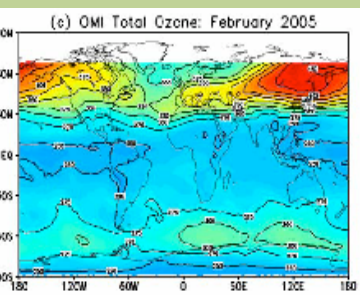## Synergetic Use of A-Train Satellite Data Sets (Aura-OMI, N16-SBUV)
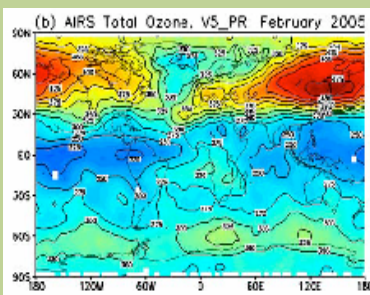

AIRS
1800 Km
Swath

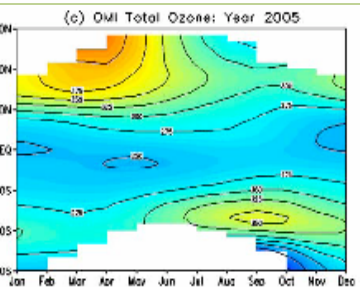Matched WOUDC BD Measurements, ECMWF, AIRS and OMI Retrievals Used in Validating AIRS Total Ozone N~4096

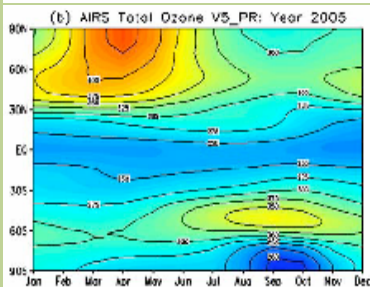AIRS TO 3 vs. BD
Global
8% RMS
4% Bias

AIRS Total Ozone
February 2005

OMI Total Ozone
February 2005

OMI
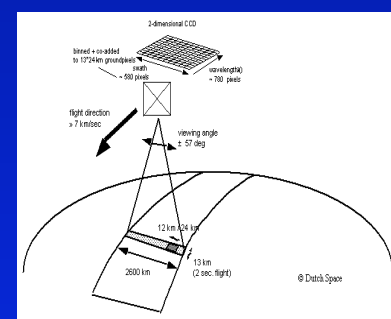2600 Km
Swath

Annual Cycle
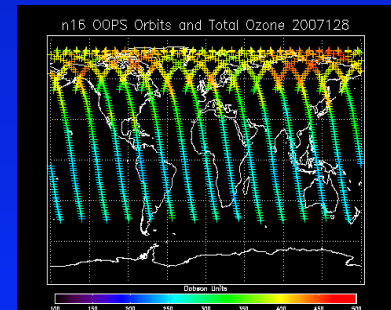AIRS - 2005

Annual Cycle
OMI - 2005

SBUV
Nadir

Divakarla et. al., 'Evaluation of AIRS Ozone Profiles and Total Ozone Retrievals with Matched O 3SNDs, ECMWF and OMI Retrievals, J. Geophys. Res., 113, D15308, doi:10.1029/2007JD009317. http://www.agu.org/pubs/crossref/20082007JD009317.shtml
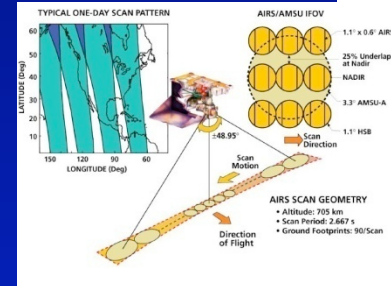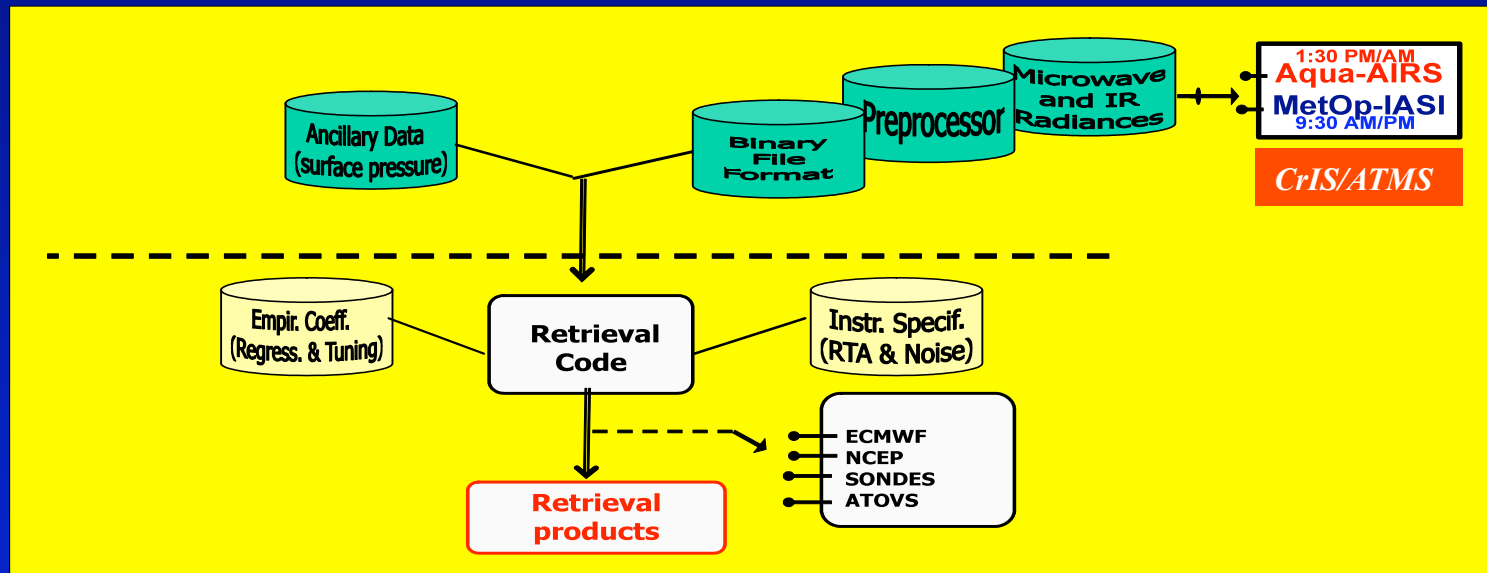
Joint Publication in Collaboration with NASA (Bill Irion, Mike Newchurch, Gordon Labow…)

NOAA Retrieval Processing System

- **The NOAA level 2 retrieval processing system was developed during the Aqua mission (AIRS/AMSU-A)**

- **Expanded to retrieve MetOp (IASI/AMUS-A/MHS) T(p), q(p), O3(p) core products, and trace gas products (CH_4, CO, CO_2 etc.)**

- **Augmented and Emerging as NOAA-Unique CrIS/ATMS Product System (NUCAPS) for the CrIS/ATMS processing.**

- **Identical systems one for research and the other for operations**
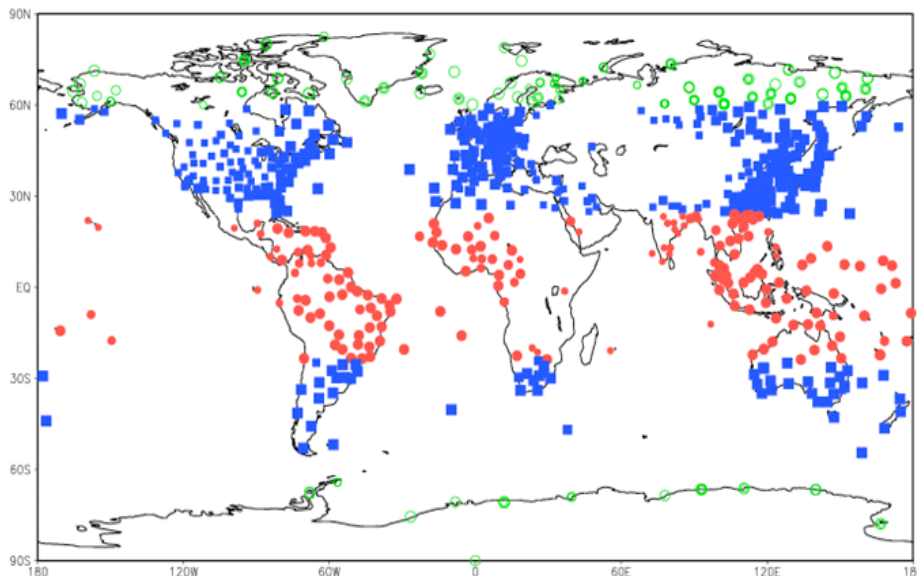   - **Reprocessing Options with Algorithm Upgrades, New Data**

http://www.orbit.nesdis.noaa.gov/smcd/spb/iosspdt/iosspdt.php#1

MetOP–IASI and RAOB Matches for Dec.2007–Jan.2009
TROP:33039 MIDLAT:71912 POLAR:17075 TOTAL:122026

Polar: 7%

MidLat: 63%

Tropics: 30%

NH: 70%

SH: 30%

ALL RAOBs and ALL Instrument Types Were Selected   (Total Number of Sites /Types:1093)
(Results will Improve Further If we do STATS with Selected RAOBs   , Inst Types)
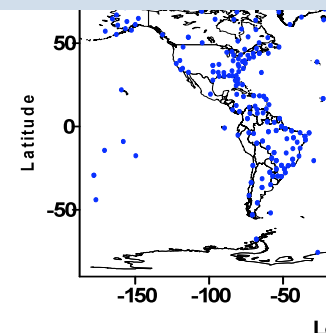
Land (34%)	Sea (17%)	Coast (49%)	ALL
22876/41182 CLDCLR (56%)	11400/18811 CLDCLR (60%)	33158/61914 CLDCLR (54%)	67434/121907 CLDCLR (55%)
237/372 CLR (63%)	1995/2369 CLR (84%)	2874/4068 CLR (70%)	5106/6809 CLR (74%)
CLR Cases (~1%)	CLR Cases (17%)	CLR Cases (8%)	CLR Cases (~7%)

IASI Statistics
Using ALL RAOBs
No Height Dependent QA

located
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IASI 9

Op-IASI, Aqua-AIRS with RA

IASI (9:30 AM/PM)

IA
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6
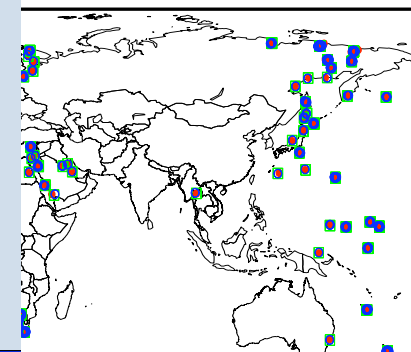
IASI Statistics – RMS - Global - Sea
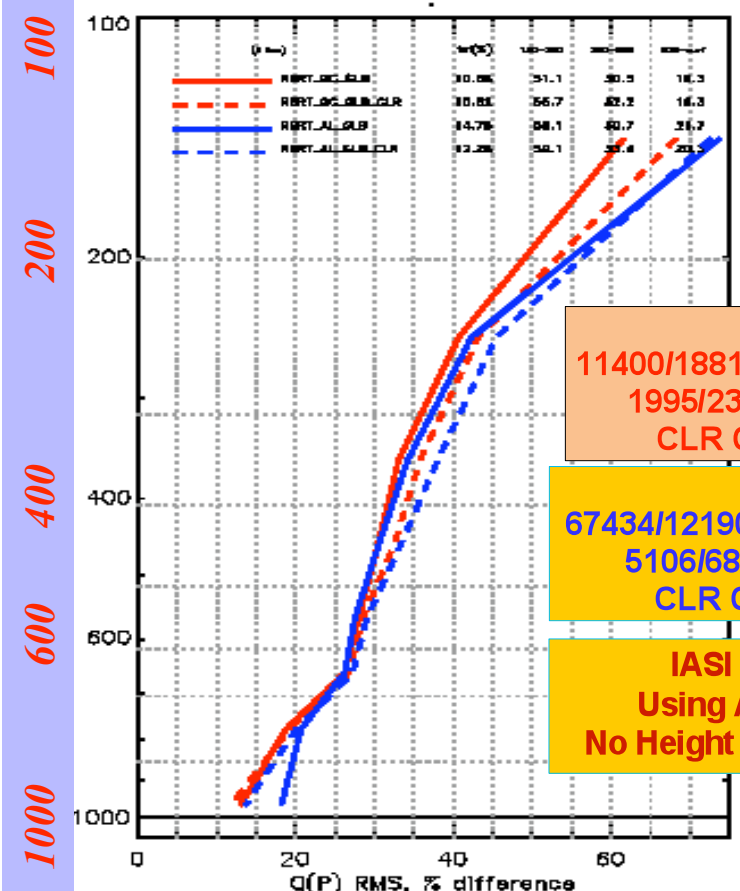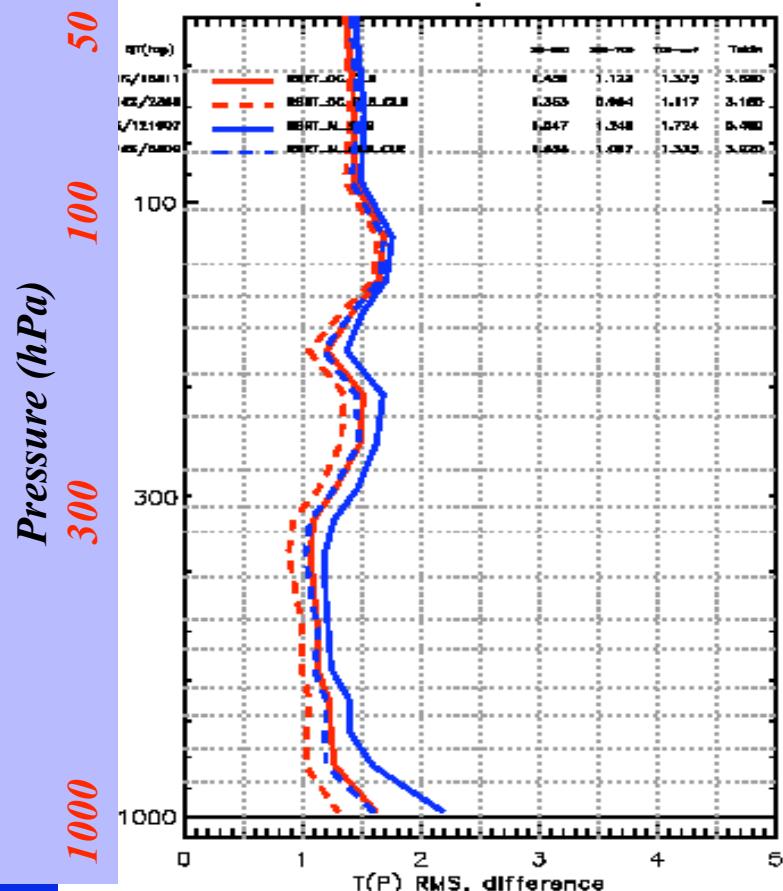## Yield : 60% , NSAMP: 11,400
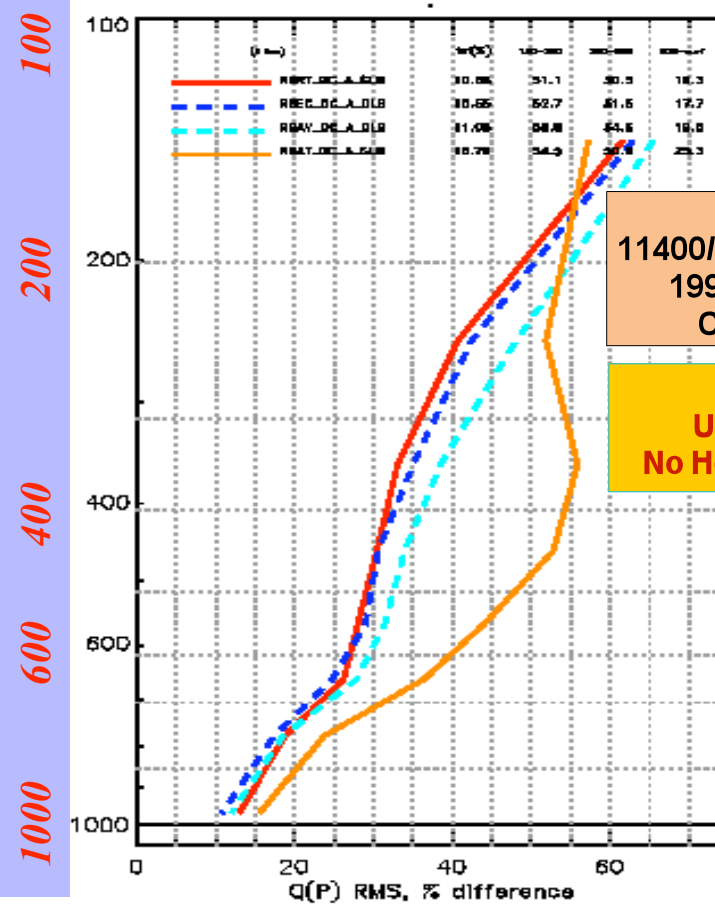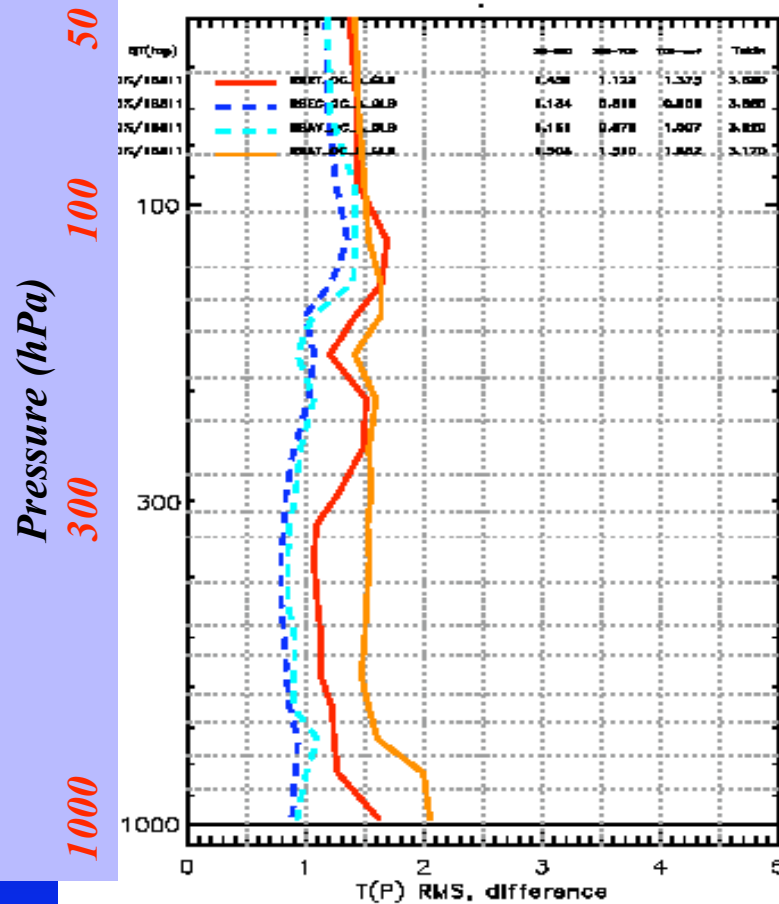
Sea
11400/18811 CLDCLR (60%)
1995/2369 CLR (84%)
CLR Cases (17%)

IASI Statistics
Using ALL RAOBs
No Height Dependent QA

RMS Difference: Left Panel for Temperature (K), Right Panel for Water Vapor (%)

RAOB vs. IASI-RET ECMWF, NCEP-GFS, ATOVS

IASI RET Statistics – RMS – GLOBAL Sea, ALL(Land+Sea+Coast) Sea - Yield : 60% NSAMP: 11,400 (CLDCLR), 1995 (CLR), ALL (L+S+ C) : Yield :55% NSAMP: 67484 (CLDCLR), 6106 (CLR)

Sea
11400/18811 CLDCLR (60%)
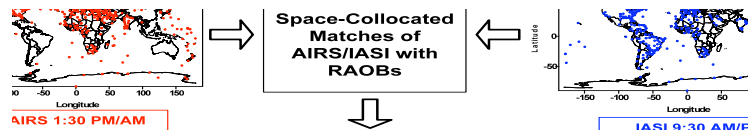1995/2369 CLR (84%)
CLR Cases (17%)

ALL
67434/121907 CLDCLR (55%)
5106/6809 CLR (74%)
CLR Cases (~7%)

IASI Statistics
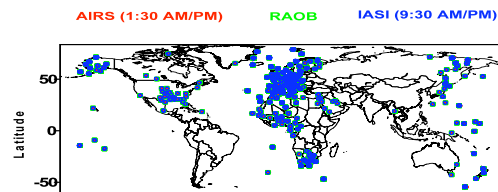Using ALL RAOBs
No Height Dependent QA

RMS Difference Left Panel for Temperature (K), Right Panel for Water Vapor (%)

RAOB vs. IASI-RET: CLDCLR-Sea (CLR-Sea) (CLDCLR-ALL), CLR-ALL

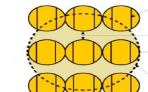# AIRS and IASI Validations with Global RAOBs/ECMWF Analysis

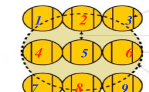Matched Locations of MetOp-IASI, Aqua-AIRS with RAOBs

AIRS (1:30 AM/PM)   RAOB   IASI (9:30 AM/PM)

IASI Retrievals (4 FOVs)   AIRS Retrievals (9 FOVs)   AIRS Like IASI 4 FOVs 2,4,6,8

Validation of AIRS and IASI Temperature and Water Vapor Retrievals with Global Radiosonde Measurements and Model Forecasts

Murty Divakarla[a], Christopher Barnet[b], Mitchell Goldberg[b], Tom King[c], Eric Maddy[a], Xingpin Liu[c], Fengying Sun[c], Zhaohui Cheng[c], Antonia Gambacorta[a], and Lihang Zhou[a]

OSA, HISE, 2009, Vancouver, Canada

Murty's presentation at AIRS Science Team Meeting, October 2008, Greenbelt, MD.

Eric Maddy's study with Gridded Data Sets.

Currently Revisiting this Effort With latest AIRS ~V6 and latest IASI RET Version.
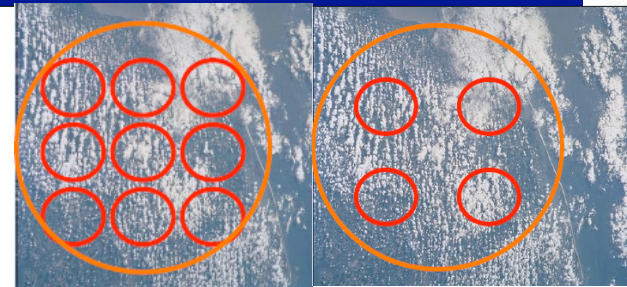
	AIRS	IASI
FOR (50Km)	**9 FOVs**	**4 FOVs**
Channels Used for CC	**58 (LW, Window)**	**69 (LW,SW Window**
Ampl Factor	**1/3 = A = 10**	**1/2 = A = 10**
Error in ή	**Probably Lower**	**Probably Higher**
Cloud Contrast	**Probably Higher**	**Probably Lower**

- IASI 4 FOVs – Tendency of confusion with Overcast (Especially over Polar Regions)
- AIRS produces at least 5% high quality CCRs
- AIRS like IASI experiment (4 FOV AIRS) with real data shows a slight advantage in cloud - clearing compared to IASI retrievals . This could be due to the geometry of the AIRS FOVs (Overlapping and spread -out) vs. IASI FOVs (Circular and Closer) where AIRS might be having a better S /N compared IASI .

- **CrIS/ATMS Proxy SDRs from IASI/AMSU-A/MHS, and CrIMSS EDRs with CrIMSS_LaRC_V1.5**

  » **Proxy SDR Algorithms**
  – CrIS Proxy – Xu Liu and Kizer (LaRC)
  – ATMS Proxy - Bill Blackwell (MIT)

  ● **CrIMSS EDR Generation**
  – CrIMSS_LaRC_V1.5 EDR Algorithm (Ported - Xu Liu and Kizer)
  – **Implementation at NOAA/STAR, Northrop Grumman**

  – **Data Sets**
    ● Focus Day (10/19/2007) Data - MetOp IASI/AMSU-A/MHS, ECMWF, AVN
    ● MetOp Global Data (MGD) Matches of IASI/AMSU-A/MHS/ECMWF/

Steps for Generating CrIS proxy data from IASI

– Matching spectral resolution between two FTS instruments are easy and exact
  1. Transform the IASI spectrum into interferogram via FFT
  2. Truncate the interferogram according to the maximum OPD of the lower-resolution FTS instrument
  3. Divide the interferogram by the IASI apodization function
  4. Multiply the interferogram by the CrIS apodization function
  5. Perform inverse FTT to convert the modified interferogram into spectral domain
  6. Interpolate 4 IASI FOV to 9 CrIS FOV
– Use can choose from three apdization functions for CrIS
  • Unapodised, Hamming, and Blackmam
– Can include local angle adjustment before step 6

Excerpts from : Murty et al., "Preliminary Evaluation of CrIMSS EDR Products with The CrIS/ATMS Proxy Data Package", SOAT Meeting, June 2010.

EVALUATION OF CRIS/ATMS PROXY RADIANCES/RETRIEVALS WITH IASI RETRIEVALS , ECMWF ANALYSIS AND RAOB MEASUREMENTS

Murty Divakarla[1], Chris Barnet[2], Mitch Goldberg[2], Xu Liu[3], Bill Blackwell[1], Eric Maddy[5], Guang Guo[5], Susan Kizer[3], Tom King[5], Walter Wolf[2], Antonia Gambocorta[3], and Kexin Zhang[5]

IGARSS-2010

Data Sets for CrIS/ATMS Proxy Data Generation and EDR Product Evaluation
(b) Focus Day Data Sets

Consists of

236 Granules of Matched Datasets for the 'Focus Day' October 19, 2007

» **Each Granule Contains 22 or 23 Scan Lines of**

– **CrIS/ATMS Proxy SDRs**

– **IASI/AMSU-A/MHS SDRs**

– **CrIMSS EDR products**

– **IASI EDR Products from NOAA IASI Operations (NUCAPS)**

– **NCEP-GFS and ECMWF Analysis Fields**

"The CrIS/ATMS Proxy Data Package for CrIMSS EDR Evaluation Delivered to IPO"

Users Can download the data from:

ftp://ftp2.orbit.nesdis.noaa.gov/smcd/tking/IPO_REL_V1.0

Approximate Granule Locations
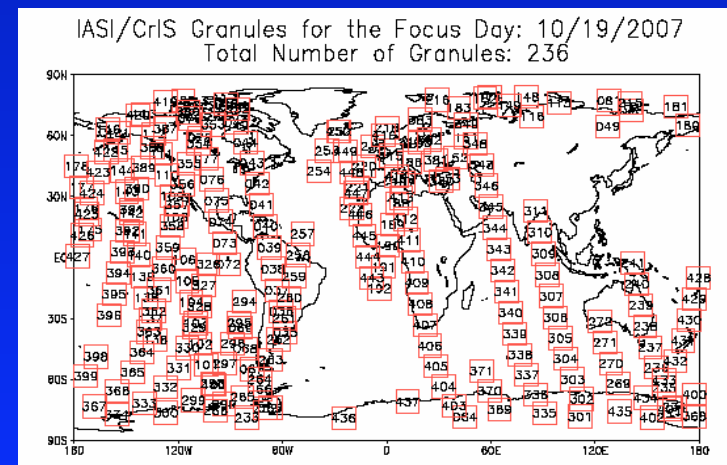**Size Not to Scale**

Useful For

- Global Perspective - ECMWF/GFS is Globally Available

- Bias Tuning for the CrIS and the ATMS

- Choose granules that have varying degree of difficulty (easy, moderately hard, tough polar cases, etc)

IASI/CrIS Granules for the Focus Day: 10/19/2007
Total Number of Granules: 236

Microwave Integrated Resource System (MIRS) Retrieval QC – ATMS Proxy vs. AMSU/MHS Obs.
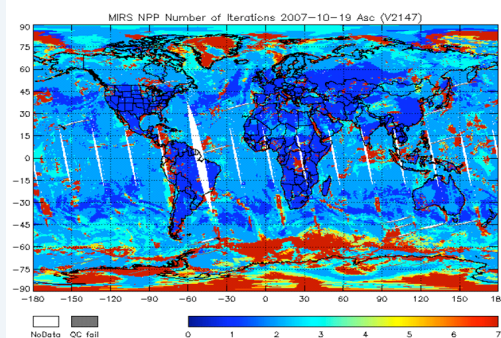## (Synergetic Use of MIRS for ATMS proxy evaluation)

MIRS – 'MW-Only' Retrieval System - Using MetOp ATMS Proxy Focus-Day (10/19/2007)
NOTE: MIRS Alg performs empirical bias-tuning to proxy-ATMS using ECMWF to generate MIRS-NPP-ATMS Proxy Retrievals Thanks to : Kevin Garrett, NOAA/STAR
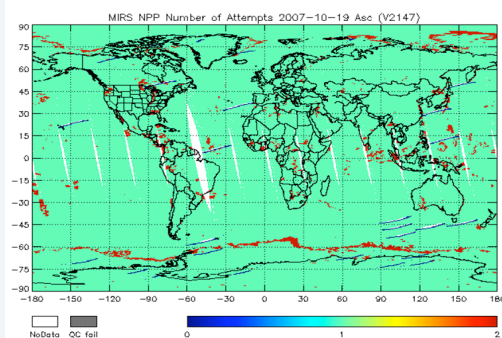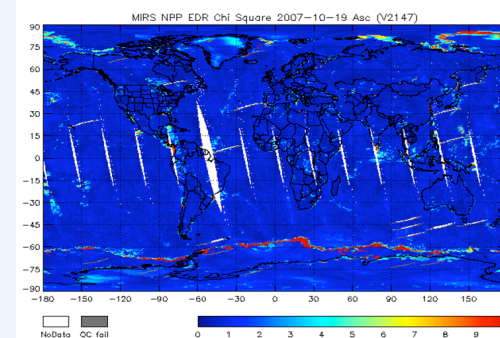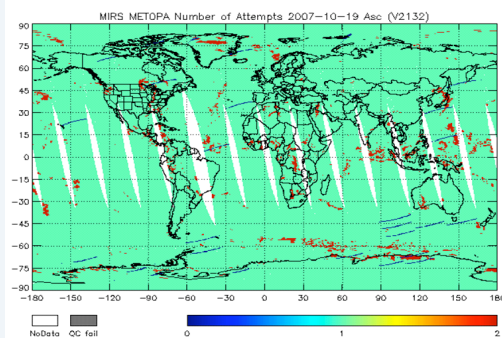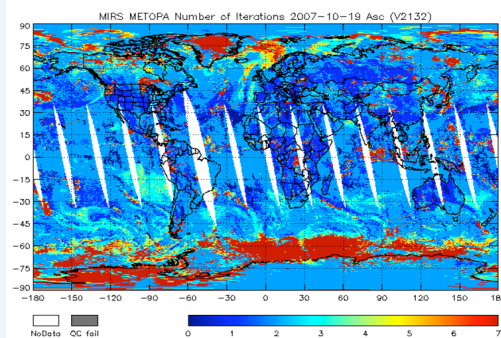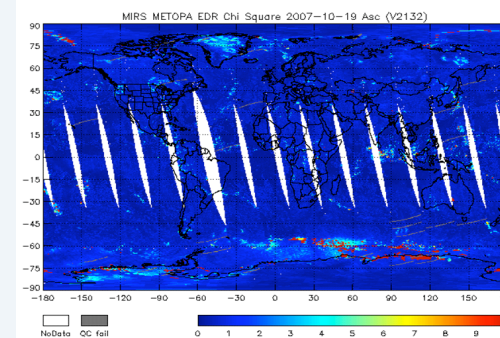
Number of Attempts	Iterations	Chi Square

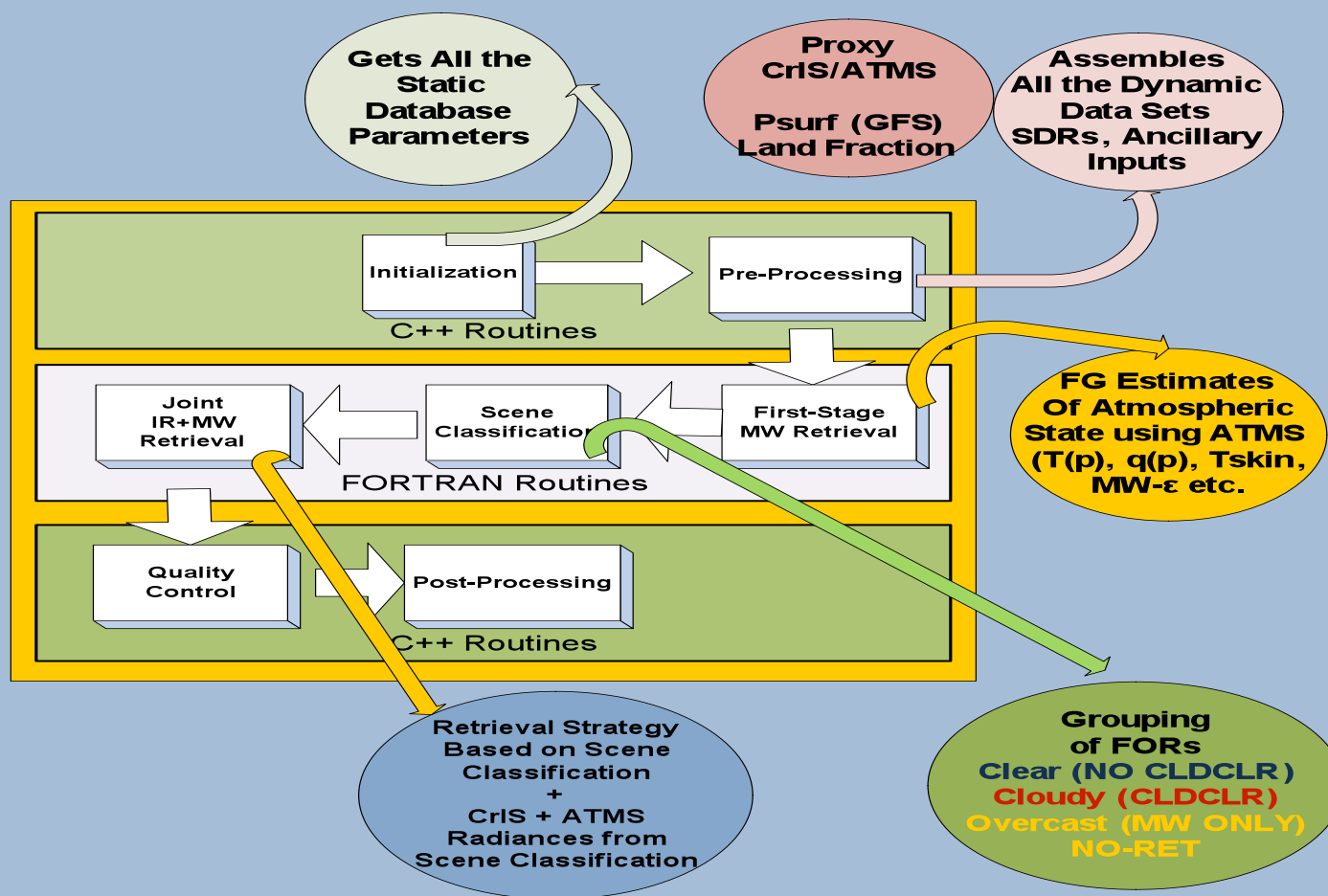| Number of Attempts	Iterations	Chi Square

MIRS– 'MW-Only' Retrieval System- Using MetOp AMSU-A/MHS Focus-Day (10/19/2007)

NGAS- CrIMSS EDR Product Algorithm
(This is different from the NUCAPS Algorithm)

Gets All the Static Database Parameters

Proxy CrIS/ATMS Psurf (GFS) Land Fraction

Assembles All the Dynamic Data Sets SDRs, Ancillary Inputs

Initialization → Pre-Processing

C++ Routines

Joint IR+MW Retrieval ← Scene Classification ← First-Stage MW Retrieval

FORTRAN Routines

FG Estimates Of Atmospheric State using ATMS (T(p), q(p), Tskin, MW-ε etc.

Quality Control → Post-Processing

C++ Routines

Retrieval Strategy Based on Scene Classification + CrIS + ATMS Radiances from Scene Classification

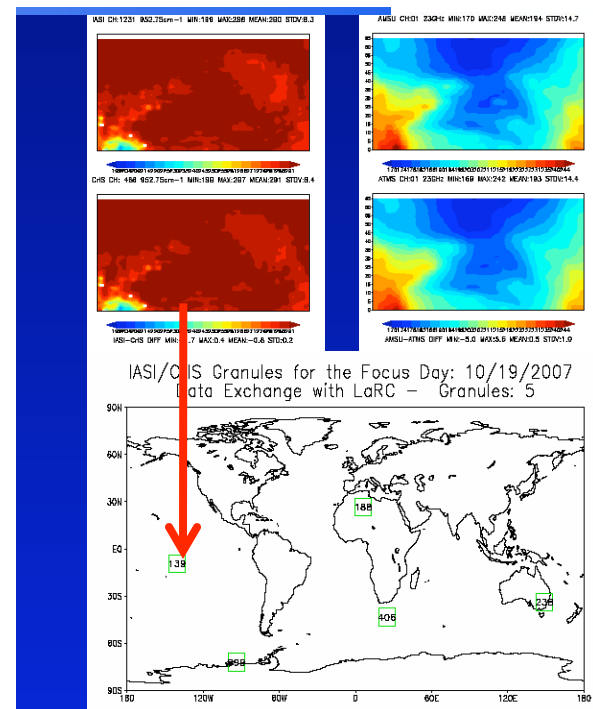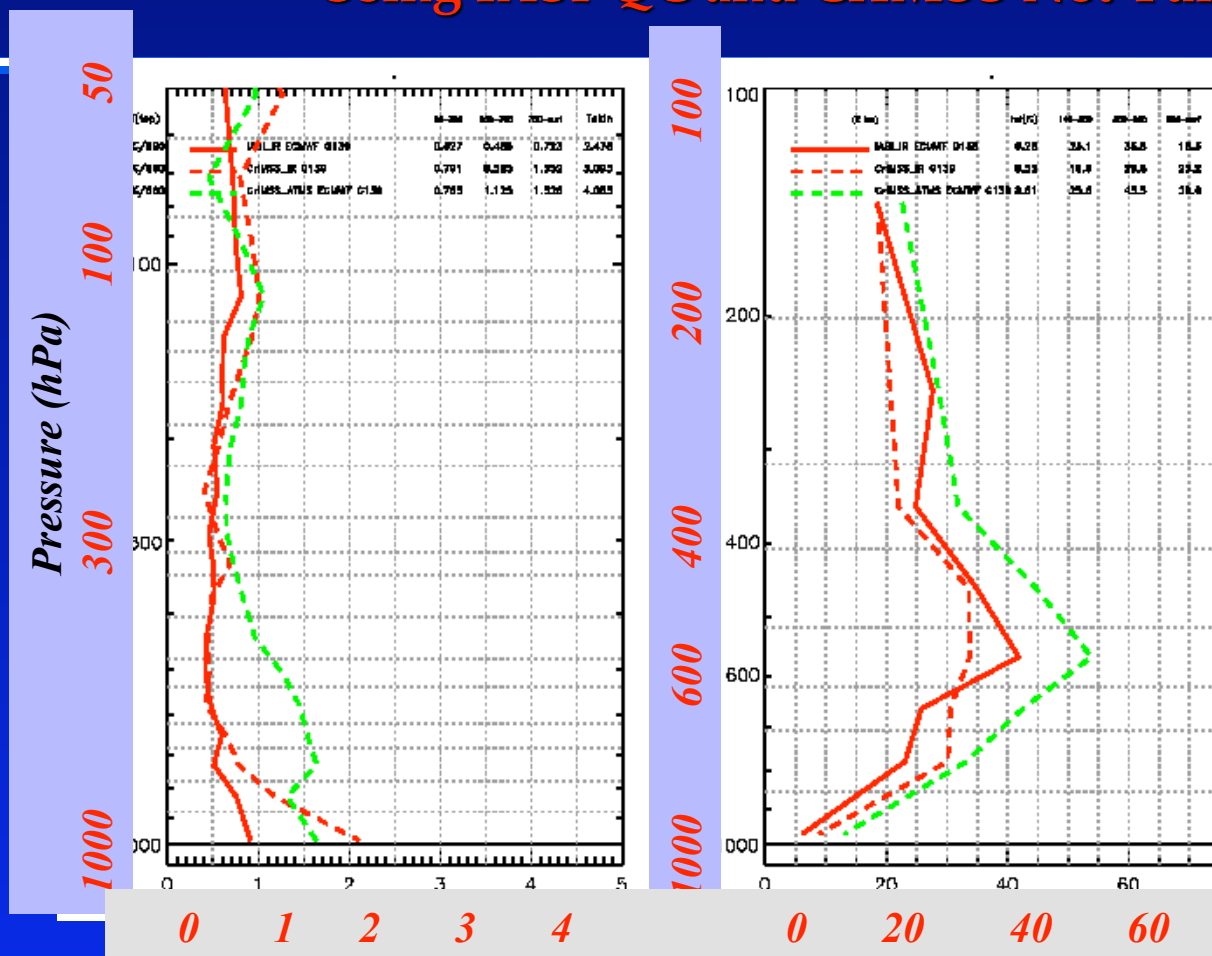Grouping of FORs Clear (NO CLDCLR) Cloudy (CLDCLR) Overcast (MW ONLY) NO-RET

Degui Gu and Xia L. Ma, "CrIMSS Retrieval Algorithm with Proxy Data", AMS, 2006.
Susan Kizer et al., 'Porting and Testing NPOESS CrIMSS EDR' Algorithms", IGARSS-2010.
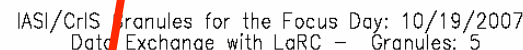Xu Liu and Susan Kizer, Porting and Testing NPOESS CrIMSS EDR Algorithms", SOAT Meeting, 2010.

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Left Panel for Temperature,   Right Panel for Water Vapor

- STDEV :ECMWF vs.. IASI (IR + MW) (Solid Red)
- SDDEV : ECMWF vs.. CrIMSS (IR+ MW) (Dotted Red)
- STDEV : ECMWF vs.. CrIMSS (MW only) (Dotted Green)

N: 588/660 %Accepted (CLDCLR) : 89%, % "CLEAR":27% (IASI Minimum CLD Amount)
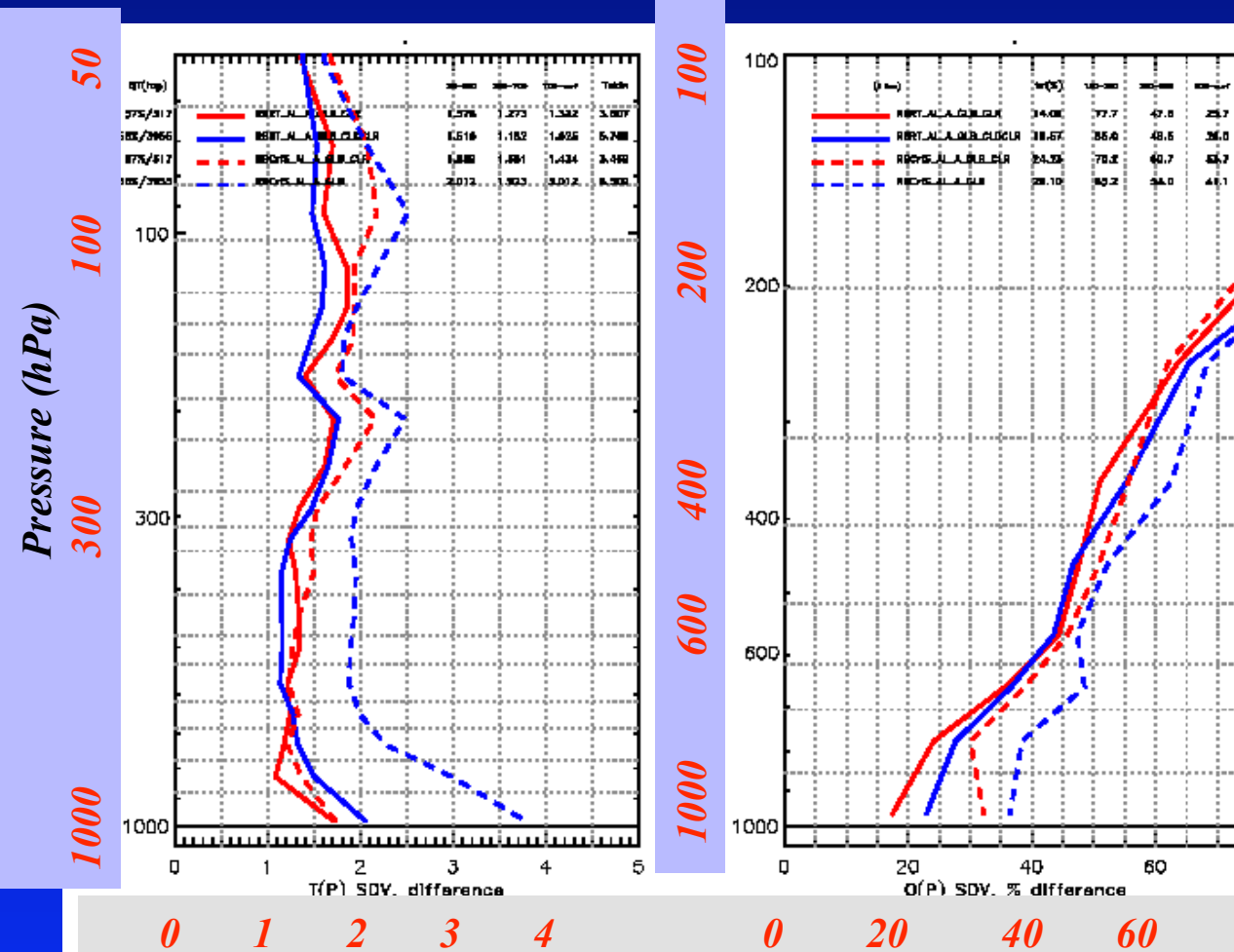
14

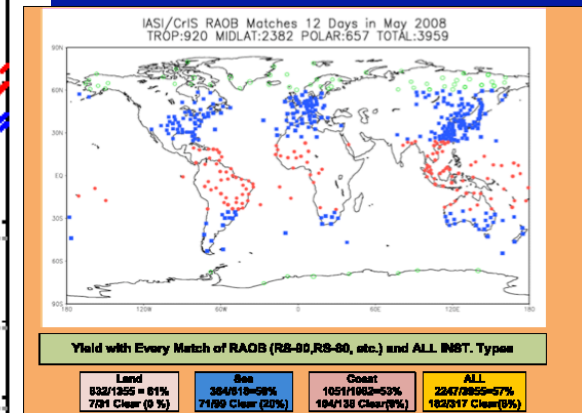**Left Panel for Temperature,   Right Panel for Water Vapor**

- Bias : ECMWF vs.. **IASI (IR + MW) (Solid Red)**
- Bias : of ECMWF vs.. **CrIMSS (IR+ MW) (Dotted Red)**
- Bias : of ECMWF vs.. CrIMSS (MW only) **(Dotted Green)**

N: 588/660 %Accepted (CLDCLR) : 89%, %'CLEAR: 27% (IASI MinimumCLD Amount)

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IASI & CrIMSS STATS with RAOBs: CLDCLR vs. "CLR"
'Using IASI-QC and CrIMSS Not Tuned'

ALL
2247/3955=57%
182/317 Clear(8%)

About 12 days of RAOB matched data sets were processed to generate CrIS/ ATMS Proxy SDRs and CrIMSS EDRs.

Data Set 'Ready to be Shipped' for Cal/Val Team

STDEV Difference: Left Panel for Temperature,   Right Panel for Water Vapor

RAOB vs.. IASI-RET(CLR),CrIMSS-(CLR) ,IASI-RET(CLDCLR) ,CrIMSS-RET(CLDCLR)

Conclusions
(Murty et al., SOAT Meeting Presentation, June, 2010)

1. **Proxy Data is Good.**
   - Evaluation of proxy data sets reveals that the proxy data have reached a scale of perfection on 'where they need to be' for EDR product generation and evaluation with truth measurements.

2. **Need bias-tuning for MW (ATMS) component (CrIS as well).**
   - The first MW retrieval is the basis for generating initial cloud-cleared radiances. We believe that the biases observed with the MW retrievals are propagating into the cloud-cleared radiances and making the IR+MW retrievals biased with respect to ECMWF and RAOB measurements

3. **The IR and MW emissivity Verification**
   - Emissivity retrieval is an intermediate product in the CrIMSS EDR algorithm. However, this is an important product that could characterize AVTP and AVMP products.

4. **CrIMSS Meeting the Specs – (Future Directions)**
   - » We expect the CrIMSS EDR algorithm to meet the AVTP and AVMP product specifications with the updated version (LaRC 1.5.1.2)
   - Latest IR and MW emissivity/ LUTs
   - Improved CrIS Noise characteristics
   - Empirical Bias Corrections in CrIMSS EDR Algorithm for the ATMS (and CrIS)
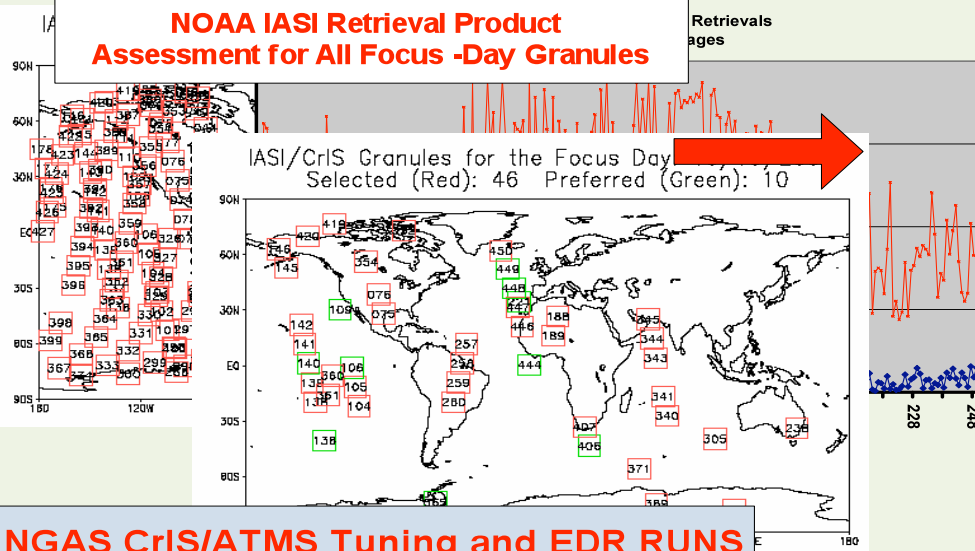   - **We have the required data sets to perform such analysis.**

NOAA IASI Retrieval Product Assessment for All Focus -Day Granules

IASI/CrIS Granules for the Focus Day
Selected (Red): 46   Preferred (Green): 10

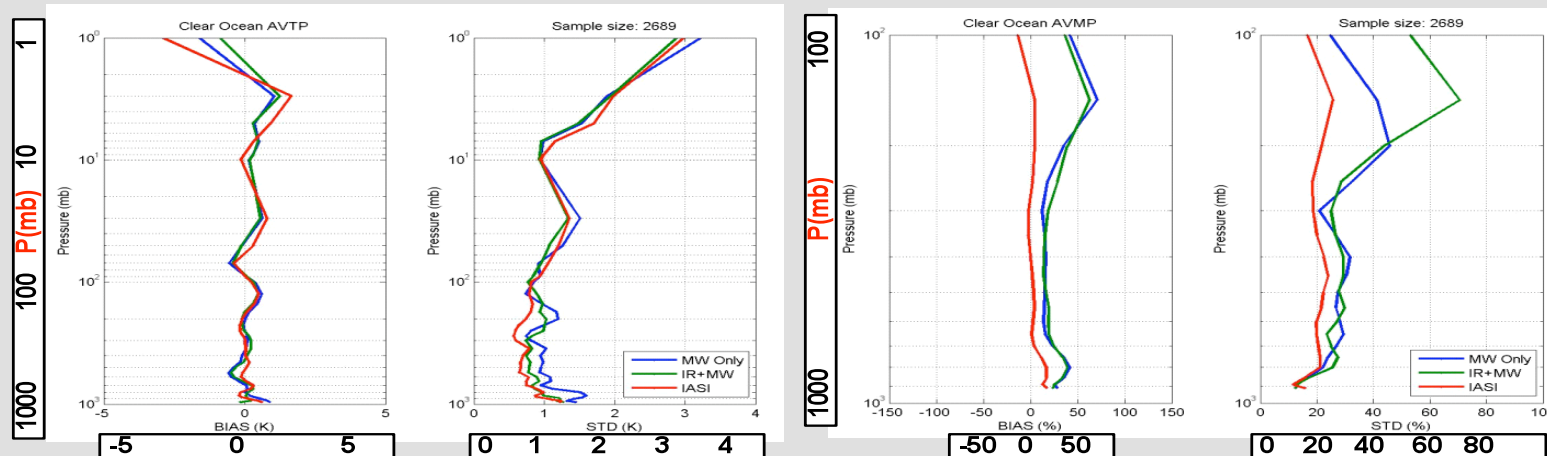**NGAS CrIS/ATMS Tuning and EDR RUNS**

- NGAS Performed EDR Evaluation
- Utilized NOAA Suggested Granules
  - IR RTM Bias Corrected
  - ATMS Bias Corrected
  - Preliminary Results on EDR Performance Evaluation
  - 47.3% CrIMSS QC Passed.
- LaRC Independently Performing Bias Tuning and EDR Assessment
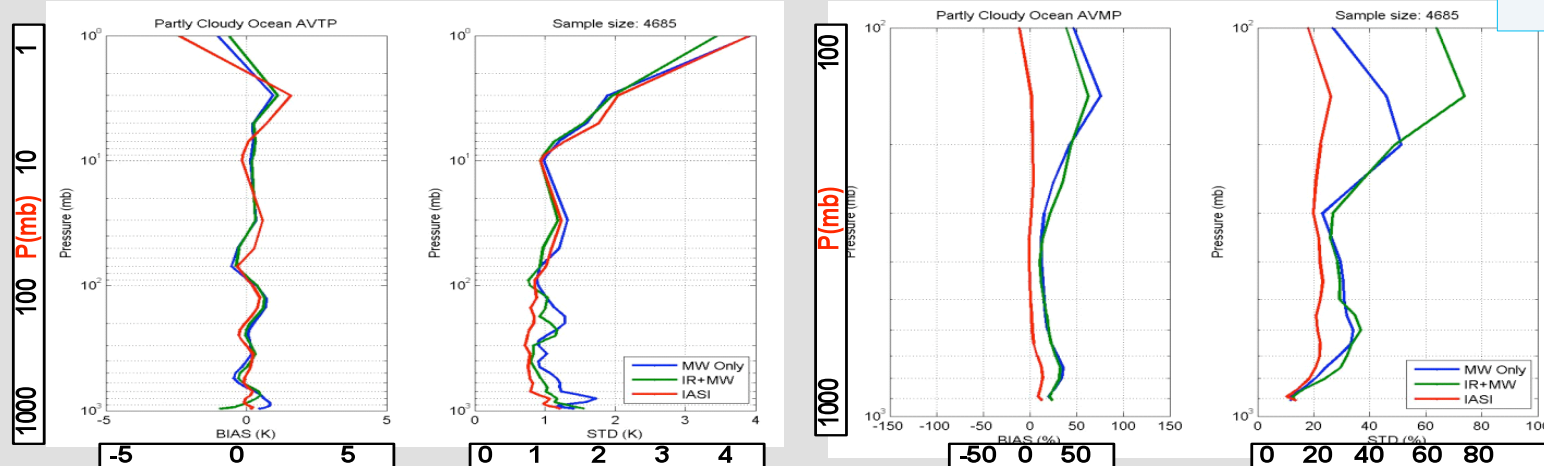- NOAA is Catching Up with Bias Tuning and EDR Evaluation

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'Clear' (No Cloud-Clearing) Ocean AVTP and AVMP

| AVTP Bias | AVTP STDEV | AVMP Bias | AVMP STDEV |

'Partly Coudy' (Cloud-Clearing) Ocean AVTP and AVMP

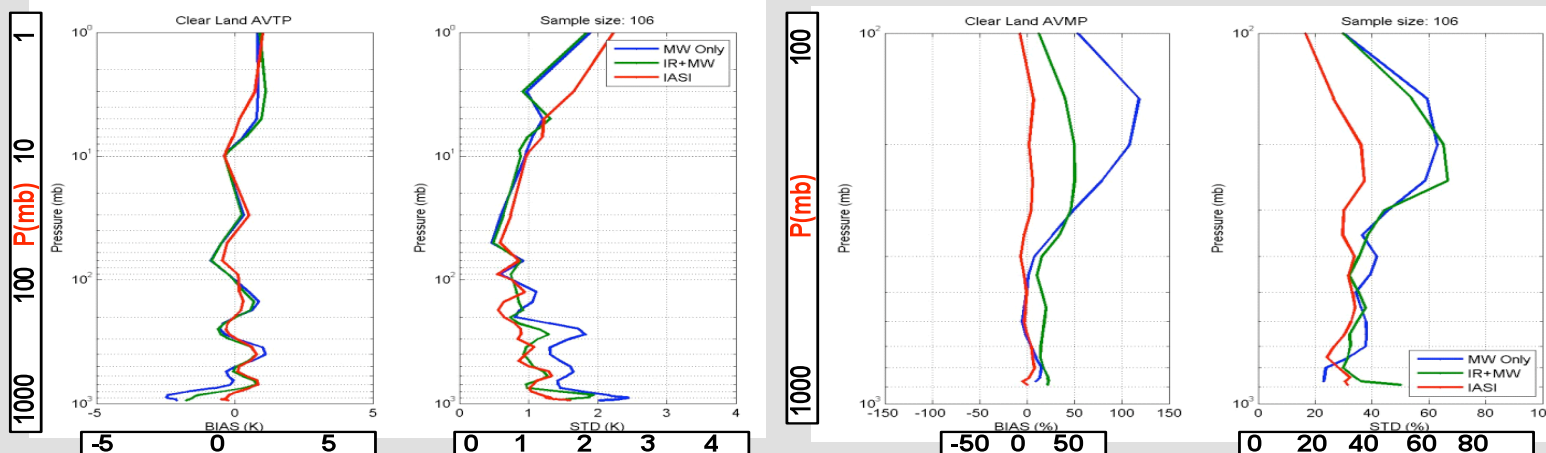| AVTP Bias | AVTP STDEV | AVMP Bias | AVMP STDEV |

MW (ATMS) Only
CrIS+ATMS
NOAA IASI

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Results from NORTHROP GRUMMAN
'Using CrIMSS QC and CrIMSS Tuned'
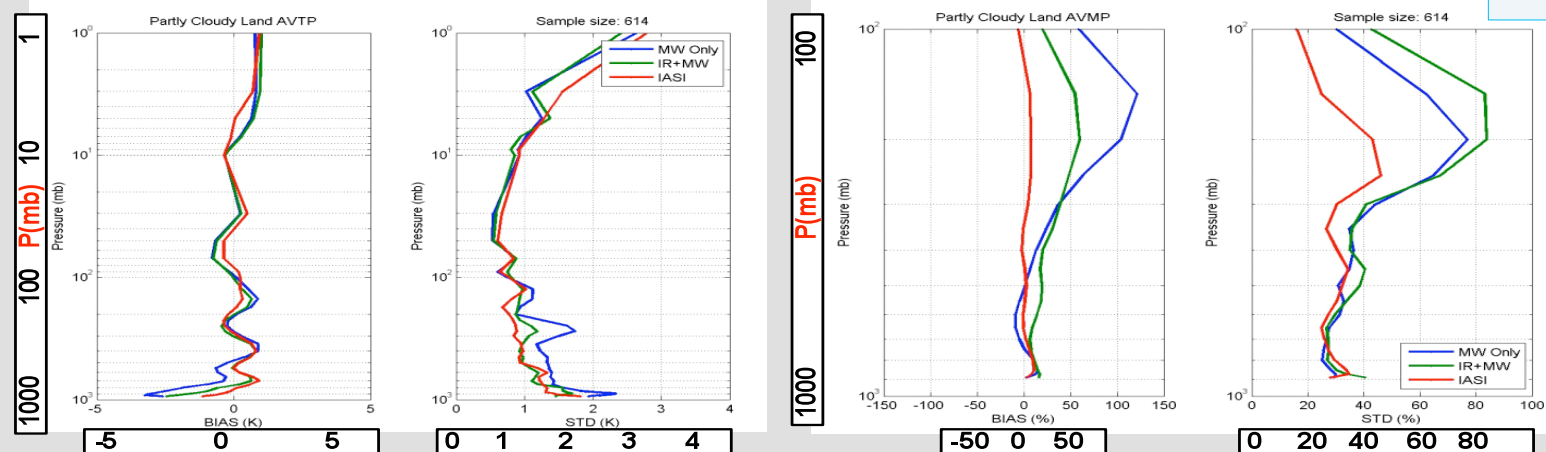### ATMS & CrIS Tuning is Critical

'Clear' (No Cloud Clearing) Land AVTP and AVMP

| AVTP Bias | AVTP STDEV | AVMP Bias | AVMP STDEV |

'Partly Cloudy' (Cloud Clearing) Land AVTP and AVMP

| AVTP Bias | AVTP STDEV | AVMP Bias | AVMP STDEV |

MW (ATMS) Only
CrIS+ATMS
NOAA IASI

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Summary
CrIS/ATMS Proxy Data and EDR Results

- Proxy SDRs generated for the Focus Day are in use at NOAA/STAR, LaRC, NGAS, and at NASA to derive CrIMSS EDR products.

- Results using the CrIS/ATMS proxy SDRs with CrIMSS EDR algorithm indicated the need for bias tuning procedures in the CrIMSS EDR algorithm (SOAT Meeting, June 2010).

- CrIMSS AVTP and AVMP products generated at NGAS after bias tuning efforts showed very good agreement with ECMWF analysis, and IASI EDRs.

- Having IASI Retrievals is very helpful as a baseline

- We anticipate that the new ATMS proxy algorithm and expected OSS RTM update will improve agreement between CrIMSS EDRs and Truth Data Sets.

- Planning on Similar analysis with RAOB Matched proxy data sets.

- Currently gearing up for Post-Launch exercises with Pre-Launch proxy data.

Backup Slides

Thank You for your Attention
Suggestions/Questions/Comments/Queries

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The NOAA AIRS/IASI/NPOESS Team

Integrated Observing System Science & Product Development Team (IOSSPDT)

NOAA/NESDIS Camp Spring, MD, USA

Overseen By

Mitch Goldberg, Chris Barnet and Walter Wolf

Post-Launch Exercises
## with Pre-Launch Proxy SDRs and EDRs
### Summary of the Telecon (10/21/2010)

- **First Telecon Meeting held - 10/29/2010 LaRC, NGAS and NOAA.**
- **Discussion on Attempts to Coordinate Efforts Among NGAS, LaRC, NOAA, NASA and Others.**
  - **Another Focus Day to Help On-Going Efforts**
  - **CrIMSS EDR V1.5 Identical Implementations**
  - **CrIMSS EDR Alg. – Bias Tuning CrIS/ATMS**
  - **Optimization of CrIS Noise File**
  - **EDR Evaluation Strategies/Statistics**

- **Another 'Focus Day' CrIS/ATMS Proxy Data**
- **Two Candidates in Consideration**
  - **10/3/2010 – IASI/AMSU-A/MHS & AVHRR**
  - **Collocated Data (Ref. Eric Maddy's Talk)**
  - **05/11/2010 (Ref. Nick Nalli's AEROSE Data)**
  - **Any Suggestions (?)**

- **EDR Algorithm - Tuning (ATMS and CrIS)**
- **Tuning of ATMS/CrIS radiances/RTM is critical to the algorithm's performance from our testing with IASI data (NGAS)**
- **Independent efforts - NGAS, LaRC, NOAA, NASA - Study Similarities and Differences**
  - **Improvements in Clear Case Detection**
    - **Use of NOAA IASI Clear Flag (and AVHRR?), apart from CLF, Scene Homogeneity). Cloud Clearing Abilities (4 vs. 9 FOVs)**
- **Remove Scan Dependent Biases in the AMSU-A/ MHS Before Attempting Bias Tuning for the ATMS**
- **Synergetic Use of MIRS (MW Only Products) to match MW Surface Type**

- **Optimization of Noise File**
- **NGAS Noise Estimates - Best EDR Performance**
- **LaRC Noise Estimates – IASI 2008 Level-1C.**
- **NOAA's Noise Estimates (Catching Up)**
- **Start with Similar Noise Estimates, and Improve Independently - NGAS, LaRC, NOAA, NASA.**
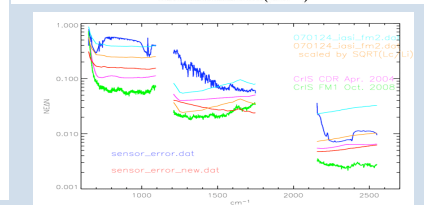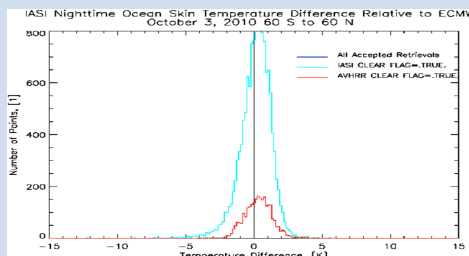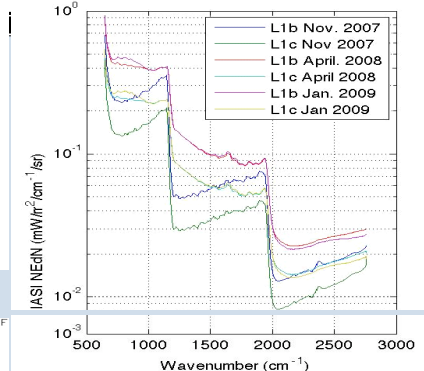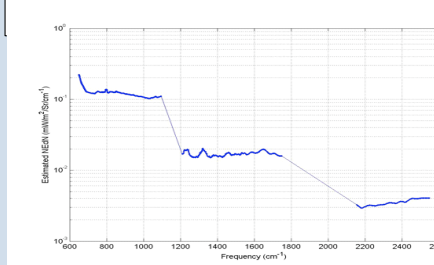
- **Unify EDR Evaluation Strategies/Statistics**
- **NOAA - Simstat – 1 km T(p), 2 km layer PCW**
  - **CLDCLR and CLEAR Cases.**
- **NGAS - Similar to NOAA simstat**
- **'cloud-free', 'clear (0-50% avg. CLF)', 'cloudy (50-100% avg. cloudiness)', and 'overcast'**
- **Statistics routines - AER science code**
- **Statistics routines - C++ OPS & post-processing**

Data Sets for CrIS/ATMS Proxy Data Generation and EDR Product Evaluation
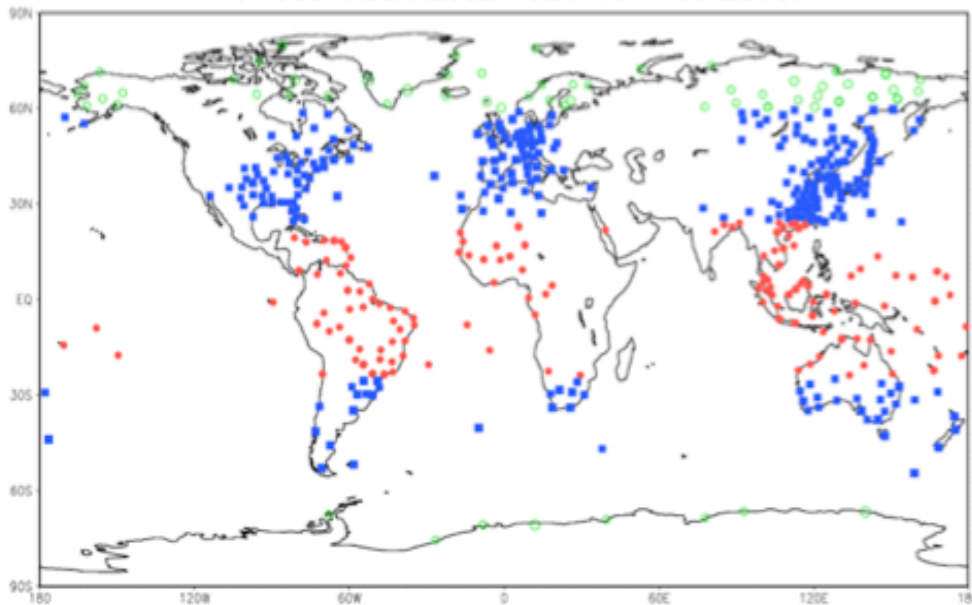## (b) MetOp Global Data (MGD) Matches

IASI/CrIS RAOB Matches 12 Days in May 2008
TROP:920 MIDLAT:2382 POLAR:657 TOTAL:3959

Yield with Every Match of RAOB (RS-90,RS-80, etc.) and ALL INST. Types

Land	Sea	Coast	ALL
832/1355 = 61%	364/619=59%	1051/1962=53%	2247/3955=57%
7/31 Clear (0 %)	71/89 Clear (20%)	184/138 Clear(9%)	182/317 Clear(9%)

Useful For

- **Global RAOBs/ECMWF/ GFS Matchups Help Show CrIMSS Meeting the Specifications**
- **We have More than 2 years of data ~ 200,000**
  - **We need to Generate proxy CrIS/ATMS !!!**
- **Both Aqua-AIRS/MetOP-IASI Common Data Matches**

About 12 days of RAOB matched data sets were processed to generate IASI and CrIMSS EDRs.

IASI Statistics – RMS- Land, Sea, ALL(Land+Sea+Coast)
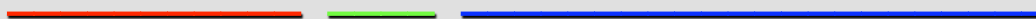## Sea: 11400 (60%) , Land: 22876 (56%), ALL: 67434 (55%)
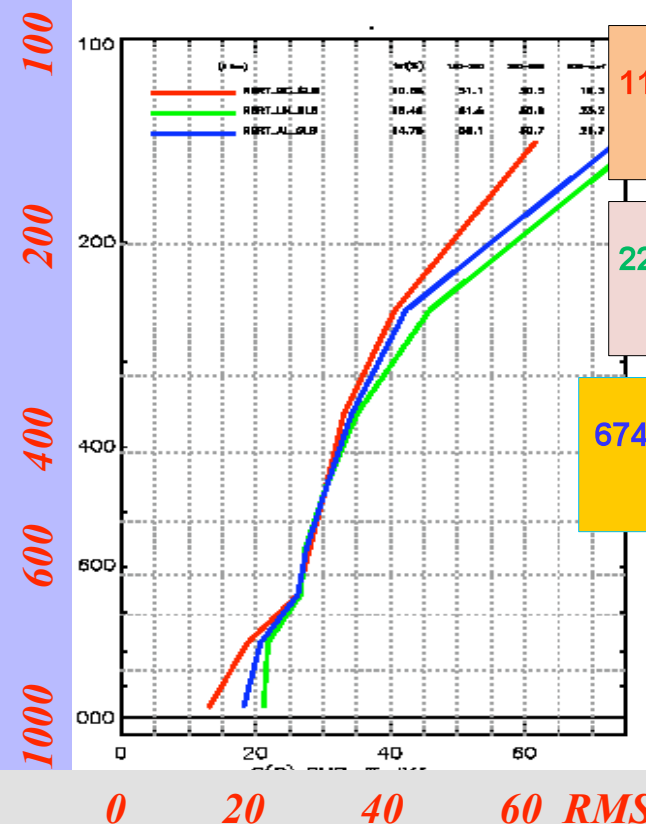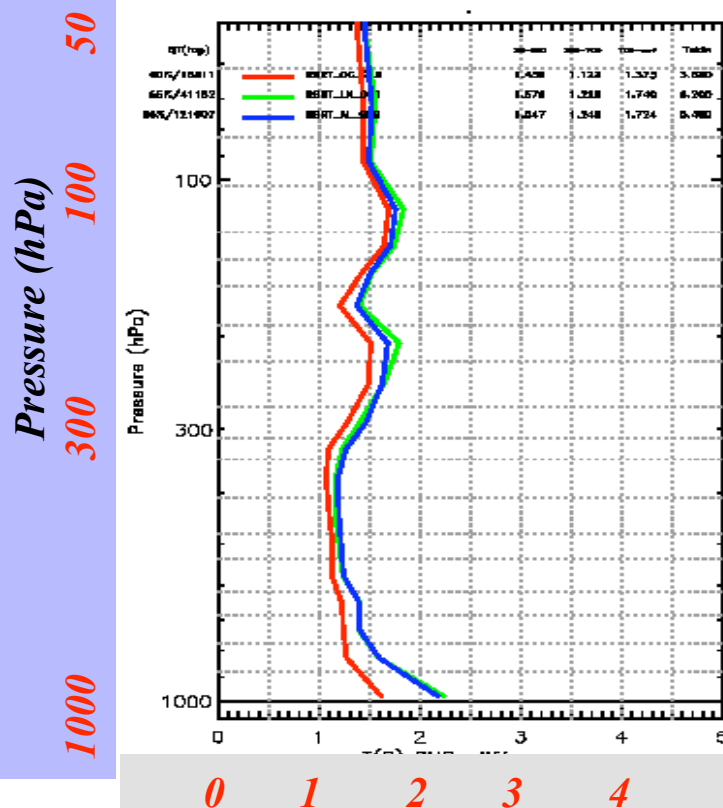
Sea
11400/18811 CLDCLR (60%)
1995/2369 CLR (84%)
CLR Cases (17%)

Land
22876/41182 CLDCLR (56%)
237/372 CLR (63%)
CLR Cases (~1%)

ALL
67434/121907 CLDCLR (55%)
5106/6809 CLR (74%)
CLR Cases (~7%)

0   1   2   3   4   0   20   40   60   RMS

RMS Difference: Left Panel for Temperature (K), Right Panel for Water Vapor (%)
RAOB vs. IASI-RET: Sea Land ALL(Land+Sea+Coast)

Golden Era of Satellite Sounders
Hyper-Spectral IR Sounders and MW Instruments
AIRS/IASI/CrIS and AMSU-A/MHS/ATMS

AIRS 9FOVs
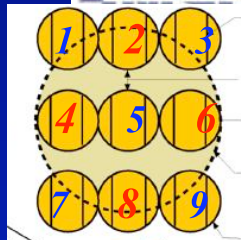
IASI 4FOVs

CrIS 9FOVs

AMSU/MHS

Aqua-AIRS/AMSU-A   1:30 AM/PM Atmospheric Infrared Sounder (AIRS) – 2378 IR Channels
MetOp-IASI/AMSU-A/MHS 9:30 PM/AM Infrared Atmospheric Sounder Interferometer (IASI) – 8461 IR Channels
NPP-C1 & C3: CrIS/ATMS 1:30 AM/PM Cross-track Infrared Sounder (CrIS) 1317 IR Channels
Advanced Microwave Sounding Unit (AMSU-A15 CH MW temperature sounder - 55 GHz Oxygen band)
Microwave Humidity Sounder (MHS 5 CH ~ 183 GHz)
Advanced Technology Microwave Sounder (ATMS – 22 CH Temperature and Moisture sounder)